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GENERAL SCIENCE.—*Some interesting applications of deuterium.*[1]

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With practically all the elements having isotopes, many in much higher concentrations than deuterium, deuterium owes its importance first of all to the large percentage difference in mass of the two hydrogen isotopes—a difference of 100 percent. As a result all differences in properties depending on mass are much greater in the case of these isotopes than in case of the isotopes of any other element. In the second place deuterium owes its importance to the electrolytic method of separation by means of which it can be obtained in a pure state conveniently and rapidly.

The electrolytic fractionation of deuterium is itself a very interesting problem. The question as to why a separation does occur has not yet been settled, but from experimental and theoretical investigations of this process, we have a much better understanding than formerly both of the evolution of hydrogen at an electrode and of its overvoltage with respect to various metals. It can be definitely stated that this separation does not result from a difference in electrode potentials of hydrogen and deuterium, the difference here being much too small. Differences in mobilities of the ions or in their rates of diffusion will not account for it. It has been deduced that the evolution of hydrogen at an electrode takes place in two steps. The first consists of the discharge of a positive H^+ ion in solution and the adsorption on the metal electrode of the neutral H atom formed. From the energy changes involved, it has been shown that these two actions take place in one step. The second step is the formation of molecules

[1] Published with the approval of the Director of the National Bureau of Standards of the U. S. Department of Commerce. The contents of this paper were presented on February 16, before the 1080th meeting of the Philosophical Society as part of a paper entitled, *The uses of deuterium and the measurement of its vapor pressures.* The vapor pressure measurements are contained in *Vapor pressures and derived thermal properties of hydrogen and deuterium* by R. B. SCOTT, F. G. BRICKWEDDE, H. C. UREY and W. H. WAHL, Jour. Chem. Physics, 2: 454. (1934), and in *The ortho- para-vapor pressure difference in deuterium* by F. G. BRICKWEDDE, R. B. SCOTT, and H. S. TAYLOR, to be published. Received Feb. 16, 1935.

from the adsorbed atoms and the desorption of the molecules from the electrode. Fractionation results from differences in the rates for hydrogen and deuterium of one or both of these two processes.

The use of deuterium enables us to do two very desirable things in chemistry. In the first place we can investigate the effect of mass

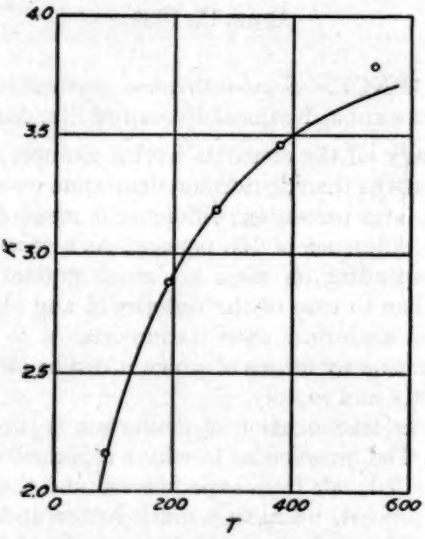

Fig. 1.—The equilibrium constant of the reaction, $H_2+D_2 \rightleftarrows 2HD$, as a function of the temperature in degrees Absolute.

independent of chemical nature upon equilibrium concentrations and rates of reaction. In the second place, hydrogen atoms taking part in chemical reactions can be tagged and distinguished from one another.

A reaction that has been extensively investigated is the reversible reaction of hydrogen with deuterium to form hydrogen-deuteride

$$H_2+D_2 \rightleftarrows 2HD.$$

The equilibrium constant of this reaction, K, a function of temperature, is

$$K(T)=\frac{[HD]^2}{[H_2][D_2]}$$

where [HD], [H_2], and [D_2] denote the concentrations of HD, H_2, and

D_2, respectively. In Fig. 1 are represented[3] the experimentally and theoretically determined equilibrium constants of this reaction. The curve representing the theoretical results was determined by the method for the calculation of thermodynamic quantities from spectroscopic data. Were it just as probable when H_2 and D_2 molecules collide for them to exchange atoms with each other to form HD molecules as it is for HD molecules to exchange atoms on collision to form H_2 and D_2 molecules, the equilibrium constant would be 4. It is seen, however, that the probability of exchange is greater for HD than for H_2 and D_2 and the concentration of HD is less than would be expected from the statistics of collisions. The underlying physical reason for the difference in the probabilities of the exchanges is the difference between the zero point energies of these three molecules, i.e., the difference between their energies at the absolute zero of temperature. When H and D atoms combine with each other, they form H_2, D_2 and HD in concentrations given by this equilibrium constant, $K(T)$. We see then that on collision H and D atoms prefer to unite with their own kind rather than to mix.

Other reactions have been investigated and the theory for the calculation of thermodynamic quantities is substantiated. To know this is important, because the experimental measurement of equilibrium concentrations is very difficult and can not be carried out with the precision or accuracy with which the constants can be determined theoretically.

The rates at which hydrogen and deuterium react with other substances are being studied. In the calculation of the rates at which substances react, factors enter that are not well understood, and satisfactory computations of reaction rates are not possible. Through investigations of the comparative rates of hydrogen and deuterium with other substances, an effort is being made to determine the effect of mass on reaction kinetics. In most cases, the rates with hydrogen are greater than with deuterium. The rates for three interesting reactions are:

$$\frac{\text{rate of } H_2+Br_2\rightarrow 2HBr}{\text{rate of } D_2+Br_2\rightarrow 2DBr} = 5.0 \quad \text{at } 308°\text{C.}$$

$$\frac{\text{rate of } H_2+Cl_2\rightarrow 2HCl}{\text{rate of } D_2+Cl_2\rightarrow 2DCl} = 13.4 \quad \text{at } 0°\text{C.}$$

[3] This Figure and Tables I, II, and III were taken from *Hydrogen isotope of atomic weight two* by H. C. UREY and G. K. TEAL, Rev. of Modern Physics, 7: 34. (1935).

$$\frac{\text{rate of } H_2+Cl_2\rightarrow 2HCl}{\text{rate of } D_2+Cl_2\rightarrow 2DCl} = 9.8 \quad \text{at } 32°C.$$

$$\frac{\text{rate of } 2H_2+O_2\rightarrow 2H_2O}{\text{rate of } 2D_2+O_2\rightarrow 2D_2O} = 2.5 \quad \text{at } 560°C.$$

To demonstrate the usefulness of deuterium in tagging or distinguishing hydrogen atoms let us consider the simple reaction that takes place when ammonia is dissolved in water:

$$NH_3+H_2O\rightleftharpoons NH_4OH.$$

Ammonium hydroxide is formed and since the reaction is reversible this decomposes into NH_3, dissolved, and H_2O. Now it is of interest to ask whether or not the same three H atoms are attached to the N atom of an ammonia molecule after the decomposition of NH_4OH as were originally attached to it. Or it may be asked if the four H atoms attached to the N of an NH_4OH molecule are equivalent. Let us consider what should happen if we dissolve ammonia in D_2O. If the four H atoms attached to the N of NH_4OH are not equivalent and the same three original H atoms are attached to the N atom after the decomposition of ammonium hydroxide, the following reaction will take place:

$$NH_3+D_2O\rightarrow NH_3DOD\rightarrow NH_3+D_2O.$$

There will be no exchange of the hydrogen of the ammonia with the deuterium of the water. If, however, the four H atoms attached to the N are equivalent then the following reactions will occur:

$$NH_3+D_2O\rightarrow NH_3DOD\rightarrow NH_3+D_2O$$
$$NH_3DOD\rightarrow NH_2D+HDO,$$

and as a result the D and H atoms of the water and ammonia will mix. Experiment shows that they do mix and that when equilibrium is reached, the relative concentrations of hydrogen and deuterium atoms in the water and ammonia are the same. This shows that all three hydrogen atoms of ammonia are in exchange with hydrogen atoms of the water.

In Tables I and II are tabulated a number of exchange reactions.

In the field of physiological chemistry, this ability to tag hydrogen atoms should prove useful. For example we can determine how rapidly a drug taken into the system is absorbed by the blood stream and then eliminated. This can be done by replacing some of the H atoms of the drug with deuterium and then analyzing for the drug by de-

TABLE I.—EXCHANGE REACTIONS BETWEEN WATER AND ORGANIC COMPOUNDS

Compound	Observation
CH_3COONa	No exchange
CH_3COOH	" "
CH_3CHO	1 hydrogen atom exchanges slowly
CH_2O	2 hydrogen atoms exchange slowly
CH_3COCH_3	Very slow exchange in neutral solution
	Faster exchange in acid solution
	Very fast exchange in alkaline solution
$CH_3COCH_2COCH_3$	All hydrogens exchange
C_2H_2	Exchange in alkaline solution
Glucose and Cane Sugar	Hydroxyl hydrogens exchange immediately
$(CH_3OH)_2$	One-third of hydrogens exchange immediately
Egg albumen	All hydrogens attached to N atoms exchange
Cellulose	All hydroxyl hydrogens exchange

TABLE II.—INORGANIC EXCHANGE REACTIONS

Reaction	Observation
$H_2(g) \rightleftarrows H_2O(l)$ and (g)	Exchange in presence of platinum
	Exchange observed in 6 weeks without addition of catalyst
	No exchange observed in 19 days without catalyst
	Exchange in 1–9.5 hours under 340–370 atmospheres pressure
	Exchange observed without catalyst in Pyrex and quartz vessels at 800° Abs.
$H_2(g) \rightleftarrows HI(g)$	Exchange observed at 400°C and above
$H_2(g) \rightleftarrows HCl(g)$	Exchange in presence of palladium at 180°C
$H_2O(l) \rightleftarrows NH_4^+$ (*sol.*)	All hydrogen atoms exchange
$H_2O(l) \rightleftarrows NH_3(l)$	All hydrogen atoms exchange
$H_2(g) + D_2(g) \rightleftarrows 2HD(g)$	Exchange at high temperatures and on catalytic surfaces. Ni, chromium oxide, Pd, Hg, Pyrex and soft glass, and charcoal at liquid air temperatures do not promote exchange
$KH_2PO_2 \rightleftarrows H_2O$	No exchange
$[Co(NH_3)_6](NO_3)_3 \rightleftarrows H_2O$	All hydrogens exchange

termining the D content of the blood. Of course the exchange reactions of the drug must have been previously investigated.

The usefulness of deuterium in biological chemistry can be illustrated by another example. Sodium formate is decomposed by enzyme hydrogenlyase of *Bacterium coli* with the formation of hydrogen and carbon dioxide. The mechanism of decomposition previously accepted for this was:

$$HCOONa + H_2O \rightarrow HCOOH + NaOH$$

$$HCOOH \rightarrow H_2 + CO_2.$$

If this is correct then replacing H_2O with D_2O the following reaction would result:

$$HCOONa + D_2O \rightarrow HCOOD + NaOD$$
$$HCOOD \rightarrow HD + CO_2.$$

No H_2 or D_2, but only HD would be formed.

Experiment shows that H_2, D_2 and HD are evolved in the equilibrium concentrations presented in Fig. 1. Moreover it has been found that in a gaseous mixture of H_2 and D_2 over water the *Bacterium coli* acts like Pt-black as a catalyst in establishing an equilibrium between H_2, D_2 and HD. It must be concluded that the previously supposed mechanism of the decomposition is not correct and that the *Bacterium coli* can react with hydrogen in the atomic form. It therefore seems probable that the decomposition of the formate by *Bacterium coli* occurs through atomic reactions with the formation of H and D atoms.

Because of the extreme sensitiveness of certain biological reactions to changes in environment, it was early realized that isotopic water might produce marked changes in many cases. At first biological effects of high concentrations of D_2O were observed by some chemists. The striking observations of *drunk* mice, the failure of tobacco seeds to sprout, and the death of guppy fish and tadpoles in D_2O, were reported. Fermentation by yeast cells was found to be so much slower that bread made with heavy water would take about one week to rise.

Later, biologists realizing that experiments carried out with low concentrations of deuterium should be more significant biologically in determining the effect of deuterium under approximately normal conditions, subjected various organisms to water containing 0.5 percent and less of D_2O. All experimenters have not found the same effects. It has been reported that *Spirogyra*, or pond scum, lives twice as long in 0.06 percent D_2O, and that some flatworms, *Phagocata gracilis*, placed in ordinary water without food shrank to 1/5 their size in five months, whereas in 0.06 percent heavy water there was only a slight diminution in size. It has also been reported that the growth of *Aspergillus niger;* the germination of conidia of the powdery mildew of wheat, *Erysiphe graminis tritici;* the root growth of wheat and the O_2 consumption by wheat seedlings showed no significant difference between the influence of ordinary water and that of water containing 0.05 and 0.5 percent D_2O. Other experiments, however, indicated that in the case of some bacteria low concentrations of D_2O—of the order of 0.5 percent—have a stimulating effect on the rate of oxygen absorption, whereas in high concentra-

tions—approaching 100 percent—the reverse is true, the rate of oxygen absorption being decreased.

In the field of nuclear physics deuterium has found one of its most important applications. It has added to the material particles used in the investigation of the structure of the nucleus, namely, the proton, neutron and α-particle, another, the deuteron (deuterium nucleus) which can be given great speeds in high voltage tubes and then used to bombard and transmute nuclei of other elements. In some respects the deuteron has proved to be more interesting than the proton. The highest energy material particles ever produced in a laboratory under controlled conditions are the helium nuclei resulting from the bombardment of Li^6 with deuterons. (The superscript designates the atomic weight of the isotope.) The two helium nuclei formed by this nuclear reaction

$$D^2 + Li^6 = 2He^4$$

have ranges in air of 13.2 cm. This is greater than the range of the longest α-particles from any of the radioactive elements. It would require 23,000,000 volts to give them their observed speeds. The transmutations resulting from the bombardment of deuterium with deuterons is unique in that it is the only known case in which a transmutation results from the bombardment of a particle with an identical particle. Two nuclear transformations can take place

$$D^2 + D^2 = T^3 + H^1$$
$$D^2 + D^2 = He^3 + \text{neutron}.$$

The symbol T denotes tritium, the hydrogen isotype of atomic weight 3. The first of these is the most abundant of all known nuclear reactions, i.e., a far greater number of transformations result per million bombarding particles than in the case of any other known reaction. The first reaction is the only one known in which another isotope of the same element is formed, instead of another element. In the strict sense of the word this is not a transmutation.

In the production of artificial radio-activity, deuterium surpasses α-particles and protons in effectiveness. It is reported that high speed deuterons render 14 of the lighter elements (Li, Be, B, N, C, O, F, Na, Mg, Al, Si, P, Cl and Ca) radioactive emitting positive electrons in their disintegration. Of these elements only B and C become radioactive under proton bombardment.

Just as deuterium made possible the investigation of the effect of mass apart from chemical nature upon chemical properties, it makes

possible the investigation of mass upon physical properties. Previously this was not possible. The change in physical properties due to difference in mass in going from one element to another is far overshadowed by the change due to the difference in chemical nature. A *pure* effect of mass on physical properties is illustrated in Table

TABLE III.—PROPERTIES OF H_2O AND D_2O

Property	H_2O	D_2O
Density$_{t_1}^{t_2}$	1.0000	1.1079
T of maximum density	4.0°C	11.6°C
Molar volume at temperature of maximum density	18.015 cm³	18.140 cm³
Lattice constants of ice a	4.525A	4.505A
b	7.39A	7.36A
Volume of the ice cell	131.0A³	129.3A³
Mole volumes of the ices 0°C	19.65 cm³	19.32 cm³
Dielectric constant	81.5	80.7
Surface tension	72.75 dynes/cm	67.8 dynes/cm
Viscosity in millipoises 10°C	13.10	16.85
20°C	10.09	12.60
30°C	8.00	9.72
Molar magnetic susceptibility liquid at M.P.	12.93	12.66
solid at M.P.	12.65	12.54
at 20°	12.97	12.75
Refractive index 20°C NaD line	1.33300	1.32828
Molar refraction 20°C NaD line	3.7121	3.665
Verdet constant $\lambda = 5893$A	0.013067	0.012556
Min./gauss·cm $\lambda = 5460.7$A	0.015395	0.014793
M.P.	0.0	3.802
B.P.	100.0	101.42
Heat of fusion	1436 cal.	1510 cal.
Heat of vaporization 25°C	10484 cal.	10743 cal.
Equivalent conductance at 18°C	H^+ in H_2O 315.2	D^+ in D_2O 213.7
K^+	64.2	54.5
Cl^-	65.2	55.3
Solubilities, molalities		
NaCl 25°C	6.145	6.145×0.92
$BaCl_2$ 20°C	1.72	1.72×0.88

III in which the properties of H_2O and D_2O are compared. The difference between the values of these properties for H_2O and D_2O are larger than was expected and as yet are not quantitatively explained.

The effect of mass is even more striking in the case of molecular hydrogen and deuterium at low temperatures. The boiling and freezing point temperatures, in degrees absolute, of hydrogen and deuterium and their corresponding vapor pressures are given in Table IV. Table V contains the latent heats of transition and the densities of the solids.

At the freezing point of hydrogen, 13.92° Abs., the vapor pressure of solid deuterium is only 5 mm of Hg or 1/11 of that of solid hydrogen. Before the vapor pressure of deuterium was measured it

TABLE IV.—Boiling and Freezing Points

	T in Degrees Absolute	Vapor Pressure mm of Hg	
		H_2	D_2
Boiling point of deuterium	23.59° Abs.	1753	760.0
Boiling point of hydrogen	20.38	760.0	256.2
Freezing point of deuterium	18.71	447.5	128.7
Freezing point of hydrogen	13.92	54	5.2

TABLE V.—Molecular Volumes and Latent Heats of Transition

	H_2	D_2
Volume of 1 gram molecule weight of solid	26.15 cm³	23.15 cm³
Heat of fusion	28 cal/mol	47 cal/mol
Heat of vaporization of liquid at 20.38° Abs.	216 cal/mol	307 cal/mol

was calculated from theory. The theory predicted that at this temperature the vapor pressure of deuterium would be 16 mm or only a little less than 1/3 of that of solid hydrogen. The observed values were introduced in the theoretical equations, and quantities were derived which could be compared with the results of other experiments. Assuming the validity of the vapor pressure theory, it was shown that the coefficient of expansion of solid hydrogen must be abnormally large and that for solid deuterium small. From the derived data, the specific heat at constant volume for solid hydrogen, a quantity which is difficult to measure and previously unknown, was calculated. In Table VI are listed values of the specific heats at constant pressure, C_p, and at constant volume, C_v. For solid hydrogen at 14° Abs. $C_p - C_v$ is 2 times C_v, and at 10° Abs., 2.7 times C_v, whereas for most solids the difference between C_p and C_v is negligibly small in comparison with C_v. This anomaly in solid hydrogen is a consequence of its large coefficient of expansion.

TABLE VI.—Specific Heats of Solid Hydrogen at Constant Pressure and Constant Volume

T Degrees Absolute	C_p Observed	C_v Calculated
10° Abs.	0.59 cal/mol	0.16 cal/mol
13.92	1.32 cal/mol	0.42 cal/mol

The differences between the physical properties of hydrogen and deuterium and their compounds are in general larger than was expected. In cases where the differences have been accounted for, new or further knowledge concerning hydrogen itself has been acquired.

As an example: It has been learned from a comparison of the vapor pressures of hydrogen and deuterium that solid hydrogen has an unusually large coefficient of expansion, and that for solid hydrogen $C_p - C_v$ is much larger than C_v itself, whereas in the case of most solids, the difference is negligibly small.

This new line of isotopic research in physics will not stop with deuterium but will be extended to the isotopes of other elements. Experiments are already under way to separate the isotopes of Ne, C, N and O in quantities large enough to determine their physical and chemical properties.

The observed differences between the biological, chemical and physical properties of hydrogen and deuterium and their compounds appear all the more striking when we recall the time when it was thought that all properties, reduced to the gram molecular basis, with the exception of those properties which depend upon the velocity of motion of the molecules, as the viscosity of a gas, were the same for all isotopes of the same element. Indeed Soddy, the discoverer of isotopes, does not call deuterium an isotope of hydrogen, because he looks upon the indistinguishability of properties, reduced to the gram molecular basis, as an essential characteristic of isotopes. It must be conceded to Soddy that hydrogen and deuterium behave like different substances but we have today a more fundamental definition of isotopes and a better understanding of the effect of mass on physical and chemical properties. As Lord Rutherford has put it, "much water has flowed under the bridge" since Soddy's discovery of isotopes in 1913.

GEOLOGY.—*Pre-Devonian structural zones in Scotland and eastern North America.*[1] ANNA I. JONAS, U. S. Geological Survey. (Communicated by W. W. RUBEY.)

Scotland, although covering a small area, about 40 miles wide and 250 miles from north to south, is of great interest geologically because it contains parts of several pre-Devonian belts of sedimentation with a complicated tectonic history. The structures which trend both northwestward and northeastward are cut off abruptly at the coast in both directions and their continuations have been sought in adjoining lands, Fennoscandia, Spitzbergen, and Greenland.

This brief discussion is based largely on the work of others and is given as the result of my participation in the second excursion of the

[1] Published by permission of the Director, U. S. Geological Survey. Received January 5, 1935.

Pre-Cambrian Association held in Scotland August 18, 1934, under the leadership of Professors Bailey, McCallien, Read and Tilley. "The International Association for the study of the pre-Cambrian and Old Mountain Chains," as it is called, was organized by Sederholm in 1930 and holds its excursions the year following the meetings of the International Geological Congress. The next field meeting will be in Czechoslovakia under the leadership of Radium Kettner of Prague. An account of the present position of the organization of the Pre-Cambrian Association and of the second excursion was published in December, 1934 (1).[2]

Pre-Devonian rocks of Scotland.—Scotland is made up from south to north of the Southern Upland, the Midland Valley, and the Highlands. The last major folding was pre-Devonian, Caledonian, in age, and all younger rocks show relatively unimportant disturbances. The Midland Valley, occupied by down-faulted Devonian and Carboniferous rocks and their intrusives and extrusives, separates the folded belts of the Southern Upland and the Highlands. The Southern Upland contains Ordovician and Silurian rocks. The Highlands are divided into 3 parts; the Southern and Central Highlands contain the Moine and Dalradian Series, both metamorphosed and folded, as were the rocks of the Southern Upland, during Caledonian orogeny. The Southern Highlands are separated from the Midland Valley south of them by a normal fault, the Highland border fault. The Central Highlands is cut in two by the Great Glen which extends along another normal fault, the Glen fault of Jurassic or younger age. The Caledonian canal follows the Glen and connects Loch Linnhe on the southwest with Loch Ness on the northwest.

In the Northwestern Highlands the Moine series has been thrust northwestward over the rocks of another orogenic belt. These rocks include the Lewisian basement of early pre-Cambrian age, composed of an igneous complex intruded into metamorphosed schists and marbles, and is overlain unconformably by late pre-Cambrian Torridonian sandstone. Both series of pre-Cambrian rocks are overlain unconformably by Lower Cambrian quartzites and the Durness limestones whose resemblance to rocks of the same age in the Appalachian Valley will be discussed later.

Moine thrust.—The Moine thrust (2) and its branches forming lower planes of disruption, the Glencoul and Ben More thrusts, produce a belt of imbricate structure 6 to 8 miles broad lying east of an undisturbed tract of Torridon sandstone and Lewisian rocks. The Moine

[2] Numbers refer to the Bibliography given at the end of this paper.

gneiss and the Lewisian igneous complex on the soles of the overthrusts have been ground out into mylonite gneisses and mylonites which were recognized and defined by Lapworth in this area in 1885. These mylonites on the Moine and Glencoul thrusts are well exposed near Knockan and on the shores of Loch Glencoul. The unravelling of the stratigraphy and tectonics of this complicated region is a monument to two great Scottish geologists, Peach and Horne (3).

Undisturbed rocks northwest of Moine thrust.—The Lewisian igneous rocks are well exposed on the shore of Loch Assynt to the Coast at Lochinver and are in large part a light and dark-banded gabbro with pink granite layers. It is a primary gneiss and according to Eskola, a product of the first crystallization of a basic magma followed by differentiation and later intrusion of the types of medium and acid composition. The gneiss is cut by ultrabasic dikes, and contains shear zones which strike northwest across the flow banding of the gneiss which is crushed to a mylonite or augen gneiss in the disturbed zones. The Lewisian gneiss (4) is exposed along the northwest coast of Scotland and in the Isle of Lewis in the Hebrides and all the igneous intrusion and folding in that area was early pre-Cambrian, pre-Torridonian, and the Torridon sandstone was deposited on the deeply eroded surface of this old land area. This sandstone series, which resembles the Triassic of the eastern United States and the Devonian of Scotland, was called Devonian before it was found that Lower Cambrian rocks unconformably overlie it. It also resembles the Jotnian sandstone of Finland and the Sparagmite formation of Norway, the youngest pre-Cambrian rocks of Fennoscandia. The folded structures of the Lewisian gneiss trend west and northwest while all younger rocks of Scotland trend northeastward. Suess (5) and others have suggested that the Lewisian basement belongs to Laurentia and in pre-Cambrian times was connected with the Canadian Shield by way of Greenland, and the whole was part of Eria, an inferred northern continent.

The crystalline schists of Loch Maree into which the granite-gabbro complex of the Lewisian was intruded, have been compared to those of the Grenville. The Lewisian igneous complex where I saw it on the shores of Loch Assynt bears a striking resemblance to the igneous complex of the Reading-Boyertown Hills in eastern Pennsylvania, which lie in the Highland belt of the Appalachian Mountains. The excursion did not visit Loch Maree and therefore I can make no comparison of the sedimentary Lewisian schists with the crystalline schists into which the igneous rocks of the Reading-Boyertown region

are intruded. The Lower Cambrian rocks of northwestern Scotland are lithologically like those in the main Appalachian Valley. The fauna in the two areas also is the *Olenellus* fauna of Arctic type.

Relations of the pre-Devonian Highland rocks southeast of the Moine thrust to those of other areas.—The rocks of the Moine and Dalradian series have only thrust relations with the rocks of Northwestern Scotland, and since they contain no fossils, their age and relations are not definitely known. The Moine series (6), composed of siliceous gneisses and schists, is considered to be pre-Torridonian by Clough, Horne, Gregory, Read, and Eskola, and to be Lewisian by Barrow and Read, and metamorphosed Torridonian by Bailey. It was intruded by the Older granites of the Inchbae and Carn Chuinneag complex (7), perhaps of pre-Cambrian age, before it was folded and metamorphosed. The Moine series at the contact with these intrusives is a hornfels with its current bedding preserved. Later deformation has affected both the intrusives and the Moine in zones striking across their contacts. Read believes that the metamorphism of the Moine series is not Caledonian because the Moine gneisses were metamorphosed before the intrusion of the Ben Loyal alkaline rocks, which are thought to be Ordovician and equivalent to the syenite rocks of the Loch Borolan area where they intrude the Durness limestones of Cambro-Ordovician age. The dislocation metamorphism along the Moine thrust has affected both the syenite and Moine gneisses. The Newer granites, of Silurian age, the Helmsdale granite, Rogart diorite, and the Strath Halladale injection (8) complex also were intruded into the Moine series after the metamorphism. At Cnok na Bieste zenoliths of Moine mica schist are included in the Strath Halladale granite and sillimanite is developed in the adjoining Moine schist. The large granite intrusions near Aberdeen belong also to the Newer granites.

The Dalradian series of quartzites, limestones, slates, and schists overlies the Moine, in part of the Highlands south of the Great Glen fault and extends to the Southern Highland border fault. Bailey believes that it is a pre-Cambrian series, younger than the Moine and overlies it, and that it was metamorphosed and folded and thrust during Caledonian orogeny into four great nappes (9). These structures the members of the excursion studied in the Appin Country south of Loch Linnhe where the Dalradian is not much metamorphosed. The more metamorphosed Dalradian described by Tilley (10) occurs in the Southern Highlands farther south and southwest of Loch Linnhe.

Robert Campbell and other Scottish geologists recognize that the Dalradian series may be Paleozoic and perhaps the metamorphosed equivalent of the folded Ordovician and Silurian rocks of the Southern Upland. This area contains no lower Cambrian rocks but was folded during Caledonian orogeny. In Western Norway where Caledonian folding has been recognized also, a metamorphosed clastic series of Cambrian and Ordovician rocks, first described by Störmer at Ustaoset in 1925, appears in the Bergen arches and has been compared by Kolderup to the Dalradian series. It carries Cambrian fossils of the Fjeld facies of the Baltic type which occurs also in the larger Cambrian belt on the border of Sweden and Norway. In Sweden, east of the border area of Lower Cambrian, is the black carbonaceous shale type of Cambrian of the normal facies of the Baltic type (*Olenus* fauna) which appears in the Midlands of England, in Wales and in Eastern North America in Eastern Newfoundland, Nova Scotia and the Boston area. This type of Lower Cambrian in Sweden and Great Britain lies south and east of the Caledonian orogeny and is not folded. The age of the Upper Cambrian Kolm of the normal series has been determined on the basis of its lead ratio as 425 million years (11).

Southern England was involved in a younger orogenesis than the Caledonian, the Armorican (Hercynian) of Pennsylvanian age, which extends into Western Europe south of the Baltic shield. It contains Mediterranean facies of the Atlantic Province not found in Eastern North America.

Caledonian folding has been recognized not only in Scotland and western Norway and Sweden but its continuation has been found in Spitzbergen and perhaps in northern Greenland. In each country the folded belt is cut off by the sea but similar formations and sequence of diastrophism appear across the water. Holtedahl (12) and other workers have established the Caledonides in Spitzbergen. Koch (13) refers the folding in northern Greenland to the Caledonian in the region between 80° and 83° North Latitude where it extends north of Pearyland across Grantland and Elsemereland on the north side of the pre-Cambrian basement that forms central Greenland. The faunas in northern Greenland are Appalachian, Arctic in type, hence belong to another trough from that of the Caledonian folded belt of Scotland and Norway. Thorolf Vogt and Resser therefore question the extension of the Caledonides to northern Greenland.

Orogenic interpretations of the structure of Scotland.—In Norway and Sweden, according to Vogt and others, the direction of movement

in the Caledonian folding is southeastward towards the Baltic Shield. Franz E. Suess (14) regarded the major direction of the movement as also southeastward. Bailey considers the Dalradian series as in part overlying the Moine, but Suess, on structural and metamorphic grounds, regards their contact as plane of dislocation. He suggests also that the Moine was the creative block which overrode southeastward over the Dalradian series which were back folded on the Moine in the process. He regards the folded non-metamorphic Paleozoic rocks of the Southern Uplands as part of the outer zone of the movement where directed pressure and not load was operative. The Baltic Shield was the foreland for the movement in Scandinavia, but in Great Britain none of the foreland is exposed.

The Moine thrust in northwestern Scotland cuts obliquely across Caledonian structure and Suess (14) believes the Moine thrust is independent of it and younger. He suggests that the Moine thrust has moved northwestward with a greater transport than is apparent and carried the rocks of the main Caledonian trough over the northwestern belt in which there are rocks of another sedimentary trough. In other words, the Caledonides are a one-sided orogen with Fennoscandia as their foreland and the northwestern movement of the Moine thrust is an unrelated and later event.

Early Paleozoic troughs of Scotland and of the eastern United States.—In the early Paleozoic, as has been said, there were two troughs of deposition in Scotland,—the northwestern with an Arctic fauna, the same as that of the main Appalachian belt, and a southern trough with a Baltic facies of the Atlantic Province. It is probable that these troughs were separated in Scotland by a low barrier in the region of the central part of the Highlands.

In eastern North America similar conditions existed in the Cambrian. The main Appalachian belt was open at the north to receive an Arctic sea and fauna like that now found in northwest Scotland and in the Hecklahook formation in Spitzbergen, part of which Holtedahl (12) considers is equivalent to the Durness limestone (13). Koch and Paulsen (15) have reported from Inglefield Land in northwestern and northeastern Greenland such trilobite forms as *Kootenia*, (*Dorypyge*) and *Wanneria*, and the brachiopods, *Paterina*, (*Qutorgina*), etc., characteristic of the Lower Cambrian of the York and Lancaster Valley, Pa. (16). In the Lower Paleozoic the main Appalachian trough continued northeast across eastern New York, western New England, the St. Lawrence Valley, and the Straits of Belle Isle. Schuchert (17)

reports in the Lower Cambrian rocks of Labrador and western Newfoundland such forms as *Micromitra*, *Kutorgina*, and *Nisusia*, a fauna that is typically developed in the Lower Cambrian of the York and Lancaster Valley and also in the Shady limestone (18) of the Southern Appalachians. Resser (18), in his paper on the generalized Cambrian time scale, discussed these faunas and their routes of migration.

The St. Lawrence seaway, until it was blotted out in the Devonian, lay west of the Green Mountain axis and its continuation in Canada, the Sutton and Notre Dame Mountains. In the basin west of the Green Mountain axis the Central Sequence of Keith (19) contains a Lower Cambrian *Olenellus* fauna the same as that of the Appalachian Valley and western Scotland. The Taconic argillaceous sequence of western New England with the Rysedorph Hill fauna of the Atlantic province of Trenton age, according to Prindle and Knopf (20), probably was deposited east of the Green Mountain axis, and owes its present position on the west side of the Green Mountains to overthrust faulting. The Cambrian found in the Boston Basin, southeastern Nova Scotia and Newfoundland contains the normal fauna of the Baltic facies of the Atlantic Province found in the area south of the Caledonian belt in Great Britain and Sweden.

Fragmentation of Eria.—Such faunal similarities in areas now widely separated by deep ocean basins have led paleontologists to the view that in Paleozoic time a land mass, Eria, extended across the northern Atlantic Ocean and afforded a means of migration for shallow-water faunas. It is known that Scotland in Tertiary time was subjected to block faulting and warping which was accompanied by the great lava flows of that period. At that time the Hebrides were cut off from the mainland by rifting. It has been suggested that this period of block faulting completed the breaking up of Eria (21). In the eastern United States similar block faulting began in early Mesozoic time at the beginning of Triassic and when the movement was completed the coastal areas of New England, Nova Scotia and Newfoundland became table lands cut off by the shore lines. The eastern part of Appalachia which may have extended 100 miles east of the present shore line, also is believed to have foundered into the depths of the Atlantic Ocean during Middle Mesozoic time. The geologic similarities on the two sides of the Atlantic have furnished the greatest support also for the Wegener hypothesis of continental drift. The Wegener hypothesis presents difficulties of acceptance perhaps even greater than that of continental fragmentation and does not come under the scope of the present discussion.

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GEOLOGY.—*Comparison of Cambrian rocks of northwest Scotland with equivalent formations of the Appalachians.*[1] G. W. STOSE, U. S. Geological Survey.

During the field excursion of the Pre-Cambrian Association across the Highlands of Scotland in August 1934, the Cambrian section in northwest Scotland was examined at several places, and the writer noted the close resemblance to formations in the Appalachians with which he is very familiar, having described and mapped them in Pennsylvania, Maryland, and Virginia. The Dalradian series, generally regarded as pre-Cambrian, which lie east of the Moine overthrust, were also examined and the writer suggests their possible equivalence to formations in the Appalachians.

GENERAL GEOLOGY

The Paleozoic rocks of northwest Scotland are exposed in a narrow belt that extends from Durness on the north coast to the east side of the Isle of Skye on the west coast, and lie in a zone between the Torridonian mountains which rise above the Lewisian upland on the west and the great Moine overthrust on the east. Members of the Pre-Cambrian Association saw only the lower part of this section, which comprises quartzites and limestones of Cambrian age, exposed in the vicinity of Loch Assynt and Loch Glencoul. Here the basal Cambrian quartzites rest unconformably on nearly horizontal Torridon sandstone, a late pre-Cambrian red grit and conglomerate closely resembling the Triassic red beds of the Appalachians and little more consolidated than those much younger rocks. These little disturbed red beds lie unconformably on Lewisian gneiss, which is exposed on the lower slopes of the mountains. The Cambrian quartzites dip gently east and form the dip slopes of the east ends of high east-west Torridonian ridges between which are deep narrow valleys, many of them occupied by long picturesque bodies of water or lochs. In the lowland east of these mountains are exposed the upper softer calcareous sandstones and overlying limestones of the Cambrian. In the vicinity of Loch Glencoul the Lewisian gneiss is thrust westward over the Cambrian rocks on the flat Glencoul thrust, a split of the great Moine thrust which lies at a higher level in the mountains to the east. The Cambrian rocks dip gently eastward under the overthrust mass, but the formations are repeated several times in shingle-like imbricate plates or schuppen structure, due to the drag of the

[1] Published by permission of the Director, U. S. Geological Survey. Received Jan. 5, 1935.

overthrust mass. The formations examined on the excursion are shown in the chart below. The faunas of the Paleozoic rocks of the Scottish Highlands have been compared with those of the Appalachian section by Grabau, Ulrich, Resser, and others, who recognized their close similarity, but comparison of the lithologic characters of these rocks has not come to my attention.

THE ROCKS

The formations studied on the excursion and those in America with which they are compared are listed in Table 1.

TABLE 1.—COMPARISON OF STRATA IN SCOTTISH HIGHLANDS AND NORTHERN APPALACHIANS

Scottish Highlands		Northern Appalachians	
Durness limestone Sailmhor group. Lower part	100′ ±	Middle Cambrian Elbrook limestone	500′
Eilean Dubh group	200′ ±	Lower Cambrian Ledger dolomite	100′
		Kinzers formation (largely shale)	150′
Grudie (Ghrudaidh) group	50′ ±	Vintage dolomite	500′
Serpulite grit Fucoid beds	30′ 50′	Antietam quartzite and Harpers phyllite	1200′
Pipe rock Lower quartzite	500′	Chickies quartzite	1500′
Torridon sandstone		Pre-Cambrian schist	
Lewisian gneiss			

The quartzites and overlying beds were examined chiefly on the north side of the east end of Loch Assynt. The basal quartzites are cross-bedded and granular and contain coarse grains of glassy quartz and pink feldspar. A few feet of coarser beds or conglomerate are reported at the base, but were not seen by the party. The higher quartzites are massive bedded and contain numerous *Scolithus* tubes and are therefore known as Pipe Rock. Worm tubes of several sizes are described, some large ones are said to be 3 to 4 inches in diameter. The total thickness of the quartzites is about 500 feet. These beds are comparable with the Scolithus-bearing Chickies quartzite in the York-Lancaster region of east-central Pennsylvania, except that in the American section the quartzite is much thicker and therefore

makes higher ridges and the basal beds are generally coarser, in places a cobble bed.

The next overlying formation, Fucoid beds, are described as dolomites, shale, mudstone, and thin beds of dolomite, weathering rusty. What was seen at outcrops is a gray to yellow fine-grained earthy rock with fine black argillaceous streaks, closely resembling the lower part of the Antietam quartzite and the sandy parts of the Harpers phyllite of Pennsylvania and Maryland. Fucoid-like markings on the bedding, whence the name, are now regarded as flattened worm casts. *Salterella* and *Hyolithes* occur throughout this formation and *Olenellus* is reported in the top layers.

The next succeeding formation, Serpulite grit, is an exact duplicate in physical appearance of certain typical quartzite beds of the Antietam of Pennsylvania and Maryland. These characteristic beds include massive white quartzites with slender straight *Scolithus* tubes a yard long; calcareous coarse grit made of round glassy quartz grains, laminated by porous fossiliferous layers, rust-stained on bedding surfaces. These beds contain many *Salterella* hence the name *Serpulite*, and also numerous fragments of *Olenellus*. All these features are duplicated in the Antietam quartzite, one of the key rocks in Lower Cambrian Appalachian stratigraphy and structure. Five species and varieties of *Olenellus* as well as other trilobites, and shells reported from these beds closely resemble, if they are not identical with, forms found in the Lower Cambrian of the Appalachian Valley. The Serpulite grit was seen to grade upward into the overlying dolomite, becoming calcareous at the top and containing rusty fragments of *Olenellus*, just as the Antietam passes into the Vintage or Tomstown dolomite in Pennsylvania.

The next overlying formation, the basal part of the Durness limestone, is called the Grudie (Ghrudaidh) group and is described as a dark, lead-colored mottled dolomite containing numerous *Salterella*. This dolomite seen at a number of places around Inchnadamph and Lake Assynt is a calcareous mud-lump rock and in appearance duplicates the knotty Vintage dolomite of central-eastern Pennsylvania, or the lower part of the Tomstown dolomite of southern Pennsylvania, Maryland, and Virginia. The Grudie is much thinner than the Vintage in America.

The Eilean Dubh group, next in ascending order, is described as a fine-grained white flaggy argillaceous dolomite and limestone. In the area visited we found most of this formation to be a dense massive

light-gray to white pure granular dolomite, weathering creamy, closely similar to the pure massive granular Ledger dolomite extensively quarried in the York-Lancaster Valley of eastern Pennsylvania. The highly fossiliferous Kinzers shale and limestone, which lies between the Vintage and Ledger dolomites in the York-Lancaster Valley, is not represented by similar rock in Scotland. All the rocks above described are of Lower Cambrian age.

Above the pure dolomite beds of the Grudie are thin layers of black oolitic chert, pitted on weathering by dissolved fragments of limestone and possibly of fossils. This is followed by buff siliceous finely wavy laminated calcareous shale or shaly limestone with interbedded thin platy layers of light gray to white fine-grained marble, which is the lower part of the Sailmhor group. This type of limestone was seen by some of the party at only one place, southeast of Inchnadamph, where they pass under a detached remnant of the Glencoul thrust block (klippe) of Torridon sandstone and Cambrian quartzite forming a mountain peak (Beinn nan Cnaimhseag). In lithologic character these beds closely resemble the Elbrook limestone, which also has chert at its base, in southeastern Pennsylvania, and which extends northeastward to the eastern part of the State and southward into Maryland and Virginia. No fossils have been found in these beds in Scotland, but the Elbrook limestone in Pennsylvania contains a scant fauna of Middle Cambrian age.

The upper limestones of the Durness group are not exposed in the area visited because, as previously said, they are cut off by the Glencoul overthrust. As the writer did not see these upper limestones he cannot make a lithologic comparison with the probably equivalent formations in the Appalachians, but fossils reported from them are assigned by Ulrich and others to the "Canadian," or Lower Ordovician, of the Appalachian Valley.

It should be emphasized that the most striking feature about the Cambrian rocks in northwest Scotland, seen by the writer, is their close similarity in lithologic character, sequence, and faunal content with formations of the same age in the Appalachian Valley of eastern Pennsylvania. The only noticeable difference is that their thickness is not so great. It seems reasonable to conclude that all these Cambrian rocks were deposited in a connected basin, probably in the same geosyncline, under very similar climatic and shore conditions, although they are now widely separated by the north Atlantic Ocean.

DALRADIAN SERIES

The Dalradian series, lying east of the Moine thrust in the Southern Highlands, is composed of thick quartzites and boulder beds, limestone, slate, phyllite, and schist that are closely folded and have a very complex structure. Apparently this series was first folded into great recumbent folds or nappes, accompanied by shearing and thrust faulting on their flanks and these flat lying overthrust beds were later closely folded. The Dalradian series is regarded by Professor Bailey, the leader of the excursion, and by some others present on the trip, as pre-Cambrian, which was the reason for their study by the pre-Cambrian Association. We saw the Dalradian series near Ballachulish, on the shores of Loch Leven and of Loch Linnhe, and at Schichallion in the Grampian Mountains. The section as at present established in the Ballachulish and Appin nappes is given below:

BALLACHULISH AND APPINN APPES	SCHICHALLION SECTION
Cuil Bay slates	Loch Tay limestone
Appin limestone	Ben Lui schist
Appin quartzite	Ben Lawers schist
Striped series	Ben Eagach schist
Ballachulish slate	Carn Mairg quartzite
Ballachulish limestone	Killiecrankie schist
Leven schist (phyllite)	Upper Schichallion quartzite
Glencoe quartzite	Tremolite limestone bed
Binnein schist	Lower Schichallion quartzite
Binnein quartzite	Main boulder bed
Eilde schist	Tempar limestone
Eilde flages (Moine)	Banded series
	Gray limestone
	Gray schist
	Tremolite limestone
	Meall Dubh quartzite
	Meall Dubh schist

Professor Bailey in his paper in the Quarterly Journal of the Geological Society of London, 1910, which is accompanied by a geologic map and sections, states that it is not known which is the top or bottom of the section, but he listed the formations in the reverse order from that in the preceding table, Eilde flags at top and Cuil Bay slates at the bottom. In his 1922 paper published in the same journal he stated that he believed the order and sequence published in the earlier report (1910) was correct because it harmonized with his interpretation of the slides as thrusts and with his conclusion that the nappes moved southeastward. In 1924 Vogt presented convincing evidence in the form of current bedding, ripple marks, etc.,

in the quartzites that the section as published by Prof. Bailey was upside down, and in 1930 Professor Bailey in a paper in the same journal accepted this inversion of the section to the order given in the chart above. It is surprising if such a complete change in order of sequence does not make necessary extensive modification of the interpretation of the structure as shown in the published sections and of the conclusions as to the direction of movement. On the excursion, Professor Bailey did not express an opinion as to the direction of movement of the nappes and where the roots of the detached nappes lay. The section in another nappe at Schichallion, now being studied in detail by Professor McCallien of Glasgow University, is given in a parallel column for comparison, but it is not yet correlated with the Ballachulish section.

Only those who have tramped the moors of the Highlands under the adverse conditions of mist and rain can appreciate the labor of the men who have toiled to unravel this complicated geology and the accurate detailed geologic maps they have produced.

A thick series of quartzites and schists at or near the base, 1000 or more feet thick at Schichallion, some quartzites containing pink feldspar grains and some beds at Schichallion containing scattered granite boulders suggesting tillite, impressed the writer in the field as having a Cambrian aspect and the finding of a possible *Scolithus* tube at one place strengthened this impression. The Leven schist, well up in the section near Ballachulish is only a phyllite, much less metamorphosed than the older Bennein and Eilde schists, which is added evidence of the inversion of the column. The black Ballachulish slate, quarried at Ballachulish for roofing purposes, is not so much metamorphosed as the Arvonia slate of Virginia, of Ordovician age. A slaty blue limestone and interbedded carbonaceous slate, called the Ballachulish limestone, impressed the writer as closely resembling the Conestoga limestone of eastern Pennsylvania, also of Ordovician age. Although no fossils have been found in these rocks, the writer ventures to suggest that the Dalradian rocks may be lower Paleozoic formations deposited in a trough southeast of the barrier represented by the overthrust Moine series, and that they may correspond to the Cambrian and Ordovician formations in the Piedmont of the Appalachians, east of the Blue Ridge-Catoctin Mountain barrier.

In the Islands of Islay and Jura, on the southwest coast of Scotland, the belt of Dalradian rocks includes thick quartzites with boulder beds, limestones, slates, and phyllites, similar to the Dalradian at Ballachulish and Schichallion, but the quartzites contain *Scolithus*

tubes, and are called Pipe rock, and other beds, containing worm castings, are called Fucoid beds. They are thus closely similar to the Cambrian rocks of northwest Scotland. Miss Elles, in a paper read at the 1934 meeting of the British Association in Aberdeen, made the statement that she believes these Dalradian rocks on Islay and Jura are Cambrian, and that similar rocks at Schichallion are probably also Cambrian. Peach and Horne, in their posthumous volume on Scotland, 1930, also assign these rocks on Islay and Jura to the Cambrian. At the British Association meeting Doctor Robert Campell also stated that he is of the opinion that beds of the Dalradian series which he has studied northeast of the area seen on the excursion are Paleozoic and he believes that fossils will some day be found to prove it.

GEOLOGY.—*A recent backshore and shoreface terrace along the Severn River, Maryland.*[1] VERNON E. SCHEID, University of Idaho. (Communicated by W. W. RUBEY.)

The ability of unusually large waves to cut a bench and build a terrace in a short time at a higher level than normal was brought to the writer's attention during June, 1934 while at the north shore of Round Bay, Severn River, Maryland. The bay, which is an enlargement of the Severn River seven and one-half miles from its mouth, measures two and one-half miles from northwest to southeast and one and one-half miles from northeast to southwest. The ordinary width of the river is one-half to three-fourths of a mile. Mouthward the river flows southeastwardly in an almost straight line to enter the Chesapeake Bay at Annapolis. The alinement of Round Bay and the lower portion of the Severn River creates a length of fetch of five miles across which the waves may gain in height and energy. The north coast of the bay is at the end of the five-mile fetch and extends in a general east-west direction from Riggs Point to Cedar Point, a distance of slightly less than one mile. Thus when the wind is from the southeast this coast is subjected to the full force of the wave attack.

This section of Maryland is part of Atlantic Coastal Plain and is here underlain by unconsolidated Upper Cretaceous sands and clays with an occasional lens of iron-cemented conglomerate. The shore of the bay is typical of the embayed coastal plain of the Chesapeake Bay region and is the result of shore processes upon a partially submerged youthful topography. The coast line is slightly crescentic and

[1] Received January 16, 1935.

there are hills at and occasionally between the points of the crescents. These same hills have been cliffed by wave action so that the cliff-line[2] presents an undulatory aspect when viewed from the water.

The center of the violent storm of August 21–23, 1933, which damaged the whole eastern seaboard, passed northward over the Chesapeake Bay region. It culminated on the 23rd with southeast gales and exceptionally heavy rain. In twenty-four hours, 7.62 inches of water fell at Baltimore and 5.00 inches at Annapolis.[3] The wind was from the northeast on the 21st and 22nd, but early in the morning of the 23rd it shifted to the southeast and attained a maximum velocity of 50 miles per hour.[3]

The unusually strong winds from the southeast backed up the tidal waters into the many small rivers and inlets of the bay. This action combined with the excessive rains produced very high tides and caused extensive river and lowland floods. For example, in the Baltimore harbor, 16 miles north-northwest of Round Bay, the high tide, which was 7.3 feet[4] above mean high tide, flooded the whole harbor section. Damage from the storm was very heavy. The State Conservation Commissioner, Mr. Swepson Earle, has estimated that about two square miles of coast land was lost in Maryland by wave action. The shift of the wind to the southeast had the same effect at Round Bay as at Baltimore. The southeast-northwest direction of the five-mile fetch allowed the storm waves to reach unusual proportions. Two young men who were at the north shore of Round Bay during the storm informed the writer that there was no exceptional wave activity while the wind was from the northeast, but when the wind veered to the southeast the water level rose approximately six feet and pounded the coast so hard as to destroy a pile-driven pier, several small sheds, and to wrench a one-half horsepower electric water pump from its fastenings and throw it fifteen feet inland and six feet higher. They report that it was during this one day (23rd) that the high-level bench and terrace described below were cut and built.

The profile of the existing backshore (BCDE) and shoreface (EFK) terraces fashioned by normal yearly wave action from the high-level bench (BC) and terrace (CDNPE) produced by the storm of August

[2] Cliff-line: The line of the top of a cliff or series of cliffs, i.e., the line resulting from the intersection of the face of a cliff, or series of cliffs, with the land surface above. Other technical terms follow the usage in Johnson, D. W., *Shore processes and shoreline development*, 1919.

[3] U. S. Dept. Agr. Weather Bur. Climatological Data—Maryland and Delaware Section 38: 29–32. 1933.

[4] Oral communication; Mr. Frank Kipp, Harbor Engineer, Baltimore, Md.

23 is shown in Figure 1. The profile has been made through one of the cliffed hills and shows the present cliff (AB) the top of which is 25 feet above the normal high tide level (EH). It also indicates the changes in the profile of the shore resulting from the wave activity of the storm of August, 1933, and the subsequent normal storms of the winter of 1933–34. BCDE represents the present backshore terrace which varies from zero to six feet wide. It is generally composed

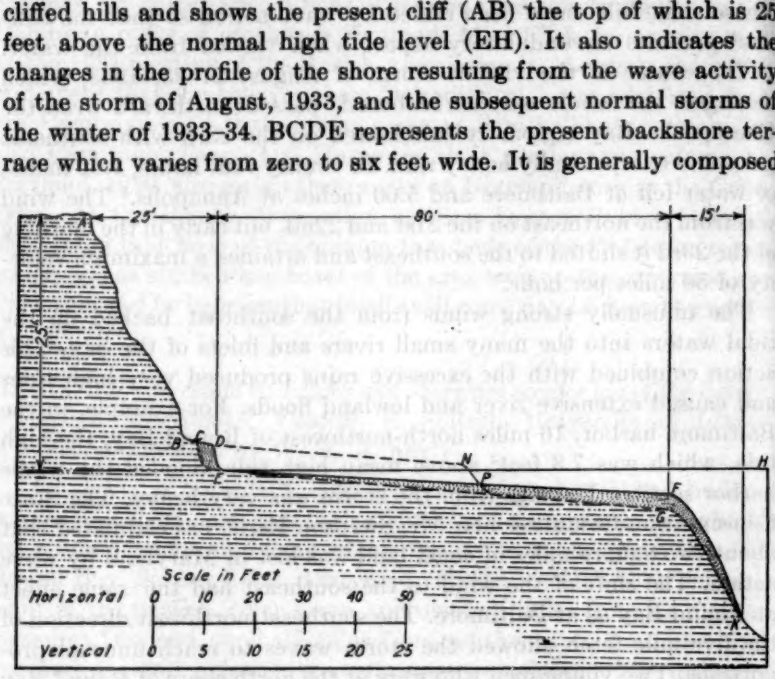

Fig. 1.—Profile of the north shore, Round Bay, Severn River, Md., June 1934.

of two parts; BC, the high-level wave-cut bench now partially covered by cliff debris, and CDE, which is the wave-built portion deposited during the storm. At places either part may form the complete backshore terrace. CE lies beneath CDE and is the basal portion of the pre-storm cliff. The top of the erosion scarp (DE) of the backshore terrace (BCDE) measures two and one-half feet above the present beach created by normal wave activities of the winter of 1933–34. The short-lived high-level terrace that was probably deposited during the storm is indicated as CDNPE. The pre-storm shoreface terrace is shown as EGK while the present shoreface terrace is shown as EFK. The material deposited by wave activity subsequent to the storm is bounded by EFKG and was probably obtained from DNPE, a part of the high-level terrace (CDNPE).

The backshore terrace (BCDE) extends the full distance from Cedar Point to Riggs Point and when seen from a few hundred feet

from shore it has the even appearance of a board walk. The terrace is evidently the result of both cutting and building by the storm waves. The unusually high waves attacked the pre-storm cliffs at the cliffed hills and cut the high-level bench (BC). The material resulting from the cutting of the new bench was immediately deposited on the pre-storm beach or carried along shore by the littoral currents and deposited on the lowland shores. With the subsidence of the storm waters a high-level bench (BC) and terrace (CDNPE) remained on the coast side of the shore. The normal yearly high tides and storm waves of the winter of 1933–34 have cut away much of the high-level terrace (CDNPE) so as to leave the present backshore terrace (BCDE). At some places where the sea cliff is unusually steep and bold no trace of the backshore terrace (BCDE) is seen. This absence may mean that the normal waves of the winter of 1933–34 were able to cut away from the exposed places not only the high-level terrace (CDNPE), but also the bench (BC) that may have been formed during the big storm.

Another effect of the storm observed by the writer was the unusual shallowness of the present shoreface. Formerly, at a distance of 90 feet from the normal high tide shore line (E), the water was four feet deep (G). At present the shoreface at the same spot is only two and one-half feet (F) below normal high tide level (EH). The depth of water at a point 105 feet from the high tide shoreline (E) was formerly and is now 15 feet (K). The new shoreface terrace (EFK) has no doubt been built by normal yearly wave activity. The high-level bench (BC) and terrace (CDNPE) left by the storm of August 23rd was cut into by the waves of the 1933–34 winter and furnished such an excessive load of debris that the waves were not able to remove it completely. This aggraded the former shoreface to form the present shoreface which at point F is two and one-half feet higher than before the storm of August 23rd, 1933.

The above described terrace is certainly not the result of an ordinary large storm unaccompanied by change in the water level. Such a storm would have attacked the pre-storm beach and would have deepened the water. But the severe storm of August, 1933, acted at a high level and probably had very little effect on the pre-storm shoreface and foreshore beach. Instead the waves immediately attacked the pre-storm cliff at a higher level than would ordinarily have been the case. The waves were supplied with an abundance of debris from the cliff so that they built out a small but high-level terrace (CDNPE) upon the surface of the pre-storm beach. The upper surface (CDN)

of the newly built terrace was quickly established as the temporary profile of equilibrium for the storm. With the recession of the storm waters the normal waves began their attack upon the newly established high-level terrace and carried much of the material seaward to aggrade the shoreface as shown in the profile.

GEOLOGY.—*Occurrence of Triassic sediments on the rim of Grand Canyon.*[1] EDWIN D. MCKEE, Park Naturalist, Grand Canyon National Park. (Communicated by JOHN B. REESIDE, JR.)

In 1858, Dr. J. S. Newberry, geologist on Lieutenant Ives' exploring expedition, recognized in the valley of the Little Colorado River where he crossed it about 40 miles below the present town of Winslow a series of rocks which was definitely above and of later age than the highest which he had seen exposed in the walls of Grand Canyon. These rocks, 500 feet thick, were for the most part red sandstones and shales and he referred to them as the "Saliferous series" or "red sandstone series."

During the past sixty years many geologists working in the Grand Canyon region have noted the presence of Newberry's "Saliferous series" in various localities and have contributed to our knowledge of the history and extent of these rocks. Among a large accumulation of data, two things appear to have especial significance. First, since the remnants of these strata are found north, south, east, and west of Grand Canyon and since they are considered on the basis of fossils to have been formed during the Lower Triassic period, it is clearly evident that rocks of this age once covered the entire Grand Canyon area. Second, these remnants furnish evidence that a long period of erosion and wearing away of the region occurred just prior to the beginning of actual Grand Canyon cutting.

South of Grand Canyon isolated remnants of the "Saliferous series" of Newberry, now known as the Moenkopi formation, are found in about nine scattered localities, the farthest southwest of which is in Sycamore Canyon. Both there and in Anderson mesa farther east the exposures are quite extensive laterally and in both cases are protected by lava caps. Since these and the other Moenkopi remnants have considerable bearing on the history of the region, their extent and nature is here summarized:

[1] Published by permission of the Director, National Park Service. Received January 16, 1935.

TABLE 1.—PRINCIPAL OUTCROPS OF TRIASSIC ROCKS SOUTH OF GRAND CANYON

Locality	Thickness	Overlying Beds	Recorder
Sycamore Canyon	300–400′ Moenkopi Cap of Shinarump	Basalt	Robinson (1)
Anderson Mesa N. Side	400′ Moenk. & Shin.	Basalt	Robinson (1)
Anderson Mesa S. Side	550′ Moenk. & Shin.	Basalt	Robinson (1)
Flagstaff	25′–150′ Moenkopi	Basalt	Robinson (1)
San Francisco Peak	? 700′ Moenkopi Shin. & Chinle	Basalt	Gilbert (2)
Cedar Ranch N.E. of Kendrick	280′ Koenkopi 365′ Shin. & Chinle	Basalt	Robinson (1)
Plateau between Diamond and Cataract Creeks	Outlier Moenkopi	None	Newberry (3)
Red Butte 14 mi. S.S.E. Grand Canyon	600′ Moenkopi 210′ Shinarump	Basalt	Ward (4)
Grand Canyon Rowe's Well	50′ Moenkopi	None	McKee
Grand Canyon west of Moran Point	32′ Moenkopi	None	McKee

Near Grand Canyon, outliers of rocks of Triassic age such as Red Butte to the south and Cedar Mesa to the east have long been recognized for what they are. Remnants of such rocks occurring actually on the rim of Grand Canyon, however, have not heretofore been recorded but since the writer has recently discovered their presence there he takes this opportunity of making known the details. Just west of the Hance trail and east of the steep hill formed by the Grandview monocline is one such exposure extending along the rim for approximately half a mile (Fig. 1). It includes the basal conglomerate member, 8 to 20 feet thick, and a maximum of 12 feet of red to yellow, thin-bedded, argillaceous sandstones above. These red sandstones are also to be seen along the Bright Angel fault not far back from the canyon rim on the road to Havasu Canyon (about two miles S.W. of Rowe's Well) but there the underlying conglomerate and the Kaibab formation are not exposed.

One important feature of the discovery of the Moenkopi formation on the rim of Grand Canyon is that it clearly shows that only a very small part of the Kaibab formation has been removed over much of this area by recent erosion. Beneath the Moenkopi is found only a thin exposure of the so-called A-member or Harrisburg gypsiferous

member of the Kaibab. It consists in this locality of two ledges of limestone, each containing abundant casts of Permian pelecypods and gastropods, separated from each other by a red sandstone. This sandstone is seen at Yaki Point and on the Buggeln hill along the Desert View road where it has been mistaken for Moenkopi sandstone because of its color. It is massive, crumbly, and irregularly-bedded, however, so there is no need for confusion if one compares

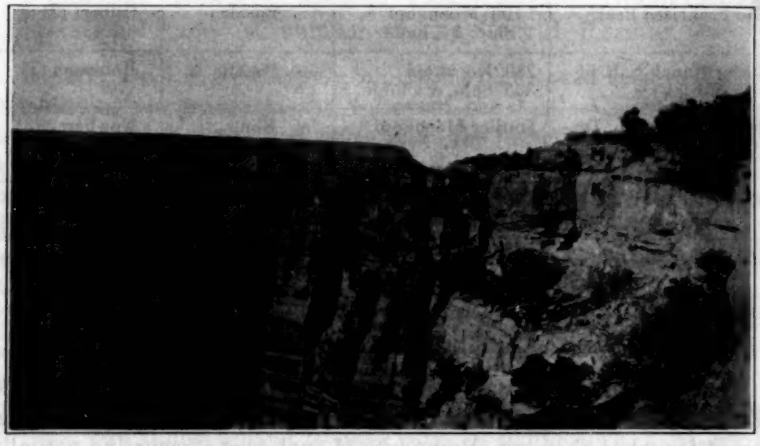

Fig. 1—Moenkopi basal conglomerate and red sandstone resting on Kaibab formation, rim of Grand Canyon, west of Hance Trail.

lithologic characters. The underlying limestone is the rock that covers a major portion of the plateau surface.

Along the rim of Grand Canyon west of Hance trail the contact between the Moenkopi and Kaibab formations, representing a break between two great eras of geological hitsory, is plainly visible. The subangular pebbles at the base of the former, ranging in diameter up to 2½ inches but averaging about ½ inch, completely cover the flat limestone surface of the latter and in places fill small depressions and channels cut into it. These pebbles are all of the most durable types of rock—jasper, chert, quartz, etc.—varying greatly in color but probably derived mostly from the Kaibab formation and transported only a short distance. A similar bed of conglomerate has been noted at the base of the Moenkopi where the writer has examined it north of Cedar Mesa, along the Little Colorado Canyon, near Cedar Ridge Trading Post, in Sycamore Canyon and in the valley of the Little

Colorado. Robinson (1) records a similar bed, 5 feet thick, at Anderson Mesa to the south while to the north and northwest it has been noted in numerous localities by other geologists so it probably represents a fairly constant unit at the base of the Moenkopi formation.

The discovery of rocks of the Moenkopi formation on the rim of Grand Canyon adds one more geological period to the remarkably great number already known to be represented in this classical cross-section of the history of the earth. Even more than ever before can the Grand Canyon of Arizona be looked upon as a most impressive open book, recording the story of the ages.

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BOTANY.—*Studies in the Gramineae of Brazil.*—I.[1] AGNES CHASE, Bureau of Plant Industry.

The grass flora of Brazil is of especial importance to American agrostology. Except for Muhlenberg's *Descriptio Graminum,* published in Philadelphia in 1817, the earliest work on American grasses (which in those days included sedges) was *Agrostografia Brasiliensis* by Giuseppe Raddi, published in 1823. More intensive botanical exploration was carried on in Brazil in the first three decades of the last century than in any other part of America.[2] Many species first described from Brazil are found in the North American tropics, for which reason it is necessary for one studying the grasses of the latter region to have a fairly detailed knowledge of the family as found in Brazil.

Since the early Brazilian collections were but poorly represented in American herbaria, three trips have been made to Brazil for the study and collection of grasses, two by the writer, in 1924–25[3] and in 1929–

[1] Received February 7, 1935.
[2] See CHASE, *Identification of Raddi's grasses.*—This JOURNAL 13: 167–169. 1923.
[3] See CHASE, *Eastern Brazil through an agrostologist's spectacles.* Smithsonian Report 1926: 383–403. 1927.

Fig. 1.—*Lithachne horizontalis* from type. Plant ×½; staminate spikelet, pistillate spikelet with immature fruit, and two views of mature fruit, ×10 dia.

30, and one by Jason R. Swallen in 1933–34. As a result of this work and of helpful cooperation from the Jardim Botanico, and the Museu Nacional, Rio de Janeiro, from the Instituto Biologico, Sao Paulo, and of Professor Bento Pickel, Tapera, Estado de Pernambuco, in addition to numerous collections of Gardner, Glaziou, Salzmann, and many others, the Grass Herbarium in Washington now has the largest collection of Brazilian grasses in the world.

The study of this material has brought to light many species previously known from but a single, often fragmentary, specimen, and also a number of undescribed species. The volume on Gramineae for the *Flora Brasilica*, projected by Dr. Frederico C. Hoehne, chief of the section Botanica e Agronomia of the Instituto Biologico, Sao Paulo, is to be prepared by the writer. It is proposed to publish in this JOURNAL from time to time the new species and notes on some of the little known ones.

Duplicate type material of new species will be deposited in the herbarium of the Jardim Botanico do Rio de Janeiro, and so far as material allows in the herbaria of the Instituto Biologico and of the Museu Nacional. Specimens of species from the state of Minas Geraes will also be deposited in the Escola Superior de Agricultura y Veterinaria, Viçosa, and those from Northern Brazil in the Museu Goeldi, Pará.

Lithachne horizontalis Chase, sp. nov.

Perennis, glabra, caespitosa; culmi steriles 10–30 cm. alti; culmi florentes longe repentes, 30–100 cm. longi, internodiis elongatis; vaginae breves; ligula minuta, fimbriata; laminae planae, oblongo-lanceolatae, 2.5–6.5 cm. longae, 8–13 mm. latae, basi inaequaliter in petiolum brevissimum subito contracta; panicula mascula terminalis, 3–4 cm. longa, 2 cm. lata, spiculis 4–6 mm. longis purpureis; spiculae feminae in nodis culmorum repentium solitariae; gluma secunda et lemma sterile 5–6 mm. longa; lemma fertile 3 mm. longum, 2 mm. latum, 3 mm. crassum, album, maturitate fusco-variegatum, cucullatum, gibbum, apiculatum; palea angusta.

Glabrous perennial in tufts of several erect sterile culms, 10 to 30 cm. tall and 1 to 4 vinelike flowering culms, these 30 to 100 cm. long, running on the ground and rooting at the nodes, simple or sparingly branching, the internodes elongate; sheaths short, slightly auricled; ligule minute, fimbriate; blades horizontally spreading, flat, 2.5 to 6.5 cm. long, 8 to 13 mm. wide, abruptly narrowed at the asymmetric base into a minute petiole hispidulous on the upper surface, the blades scabrous on the margin, especially toward the acute to acuminate apex; staminate panicles 3 to 4 cm. long, about 2 cm. wide, terminal on mostly relatively short culms, the spikelets short pediceled on the subcapillary branches, 4 to 6 mm. long, the lemma and palea purple, acute, the 3 stamens with anthers almost as long as the spikelets, the filaments very short; pistillate spikelets solitary on slender peduncles, borne at the nodes of the long creeping culms, protruding from the side of the sheath or from its summit, rarely one or two borne on the

culms producing the terminal staminate panicles, the glume and sterile lemma equal, 5 to 6 mm. long, acuminate, the glume 5-nerved, the lemma 3-nerved, both with a few obscure cross veins; fruit 3 mm. long, about 2 mm. wide and 3 mm. thick, smooth, dull white, becoming strikingly mottled with grayish brown, the lemma 5-nerved, cucullate, strongly gibbous, abruptly apiculate; palea narrow; rachilla joint remaining attached at base, as a white porcelain-like callus.

Type in the U. S. National Herbarium no. 1,255,920, collected on a moist gentle slope above streamlet, near Bello Horizonte, Minas Geraes, Brazil, March 25, 1925, by Agnes Chase (no. 9057). Known only from the type collection.

Field notes state that the plants were firmly rooted, forming a colony under coarse herbs and *Paspalum paniculatum* L., the long pistillate culms tangled under vegetation, very slender but not readily breaking in untangling; staminate panicles relatively few, the spikelets falling readily; blades flat but curling almost instantly when plants were dug. The colony was found about half a kilometer beyond the end of the Calafate bonde [street car line]. The specific name refers to Bello Horizonte, the beautiful capital of Minas Geraes, and also to the widely creeping pistillate culms.

This third species of *Lithachne* is strikingly different from the two previously known species, *L. pauciflora* (Swartz) Beauv., rather widely distributed in the American tropics, and *L. pineti* (Wright) Chase, known only from Cuba. *Lithachne pineti*, to which it is the more nearly related, is a much smaller, more delicate species, with smaller blades and spikelets, the fruits smaller, the palea pubescent with thick hairs toward the base.

OLYRA SAMPAIANA Hitchc. Journ. Washington Acad. Sci. 17: 215, *f. 1*.—1927.

The type specimen, collected at Reeve, Estado do Espirito Santo, by José Vidal, is almost without underground parts. Specimens collected in 1929 at Alegre, Espirito Santo, about 20 kilometers west of Reeve (*Chase* 10049), show that the roots bear fleshy potato-like bodies, 1 to 2 cm. long and 5 to 8 mm. thick.

BOTANY.—Centrochloa, *a new genus of grasses from Brazil.*[1]

JASON R. SWALLEN, Bureau of Plant Industry.

Material of a new genus of the tribe Paniceae was collected by the author in the state of Maranhão, Brazil, during a collecting trip in the early part of 1934. It occurs rather commonly on sterile sandy soil in the states of Maranhão and Goyaz in the valley of the Tocantins river, in the region of Carolina. The name of the genus is taken from the Greek κεντρον spur, and χλοα, grass, referring to the pointed callus which extends well below the articulation between the pedicel and the spikelet.

[1] Received for publication February 7, 1935.

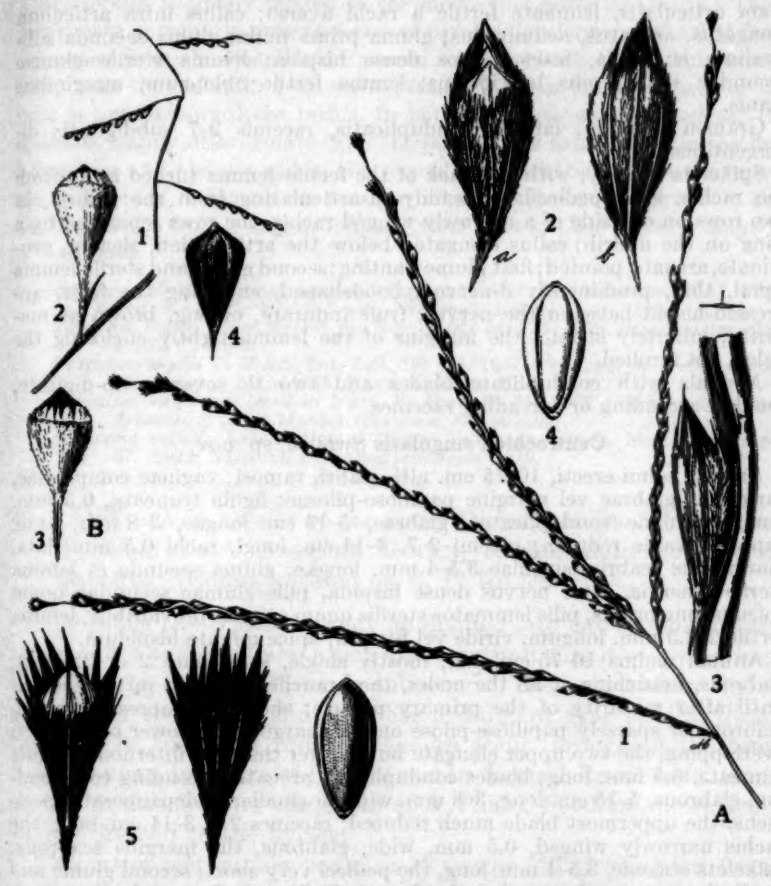

Fig. A.—*Centrochloa singularis*, from type. 1. Panicle, ×1. 2. Two views of spikelet, *a*, from side of sterile lemma, showing the glabrous summit and the scar (at summit of callus) of attachment to pedicel; *b*, from side of second glume, ×10. 3. Three-quarter view of spikelet attached to the narrowly 3-winged rachis, showing the base of callus free from the rachis; pedicel (to right) from which spikelet has fallen; Cross section of rachis (above), ×10. 4. Fruit, ×10. 5. Two views of mature spikelets and fruit, ×10, from *Swallen* 3704.

B.—*Spheneria kegelii*, from *Spruce* 884. 1. Panicle, ×1. 2. Spikelet, from side of sterile lemma, about to fall from the pedicel, showing the oblique articulation from the relatively long pedicel, ×10. 3. Spikelet from the side of second glume showing linear scar of attachment to pedicel, ×10. 4. Fruit, ×10.

Centrochloa Swallen, gen. nov.

Spiculae solitariae, biseriales, breviter pedicellatae pedicellis infra spiculam articulatis, lemmate fertile a rachi averso; callus infra articulum elongatus, arcuatus, acuminatus; gluma prima nulla; gluma secunda subhyalina, cucullata, inter nervos dense hispida; lemma sterile glumae secundae simile, pilis brevioribus; lemma fertile oblongum, marginibus planis.

Gramen annuum, laminis conduplicatis, racemis 2–7 subdigitatis divergentibus.

Spikelets solitary, with the back of the fertile lemma turned away from the rachis, short-pedicellate, readily disarticulating from the pedicel, in two rows on one side of a narrowly winged rachis, the rows separated by a wing on the midrib; callus elongated below the articulation, slender, acuminate, arcuate, pointed; first glume wanting; second glume and sterile lemma equal, thin, prominently 3-nerved, hoodshaped, enclosing the fruit, appressed-hispid between the nerves; fruit indurate, oblong, brown at maturity, minutely striate, the margins of the lemma tightly enclosing the palea, not inrolled.

Annuals with conduplicate blades and two to several sub-digitate, slender, ascending or spreading racemes.

Centrochloa singularis Swallen, sp. nov.

Annua; culmi erecti, 10–75 cm. alti, glabri, ramosi; vaginae compressae, carinatae, glabrae vel margine papilloso-pilosae; ligula truncata, 0.5 mm. longa; laminae conduplicatae, glabrae, 5–15 cm. longae, 3–8 mm. latae, suprema valde reducta; racemi 2–7, 3–14 cm. longi, rachi 0.5 mm. lata, marginibus scabris; spiculae 3.5–4 mm. longae; gluma secunda et lemma sterile 3-nervia, inter nervos dense hispida, pilis glumae secundae quam spiculis longioribus, pilis lemmatos sterilis quam spiculis brevioribus; lemma fertile 2–2.3 mm. longum, viride vel fuscum, apice minute hispidum.

Annual; culms 10–75 cm. tall, mostly single, sometimes 2 or 3, erect, glabrous, branching at all the nodes, the branches enclosed in the sheaths until after maturity of the primary panicle; sheaths compressed-keeled, glabrous or sparsely papillose-pilose on the margins, the lower ones short, overlapping, the two upper elongate but shorter than the internodes; ligule truncate, 0.5 mm. long; blades conduplicate, arcuate, ascending to spreading, glabrous, 5–15 cm. long, 3–8 mm. wide, or smaller in depauperate specimens, the uppermost blade much reduced; racemes 2–7, 3–14 cm. long, the rachis narrowly winged, 0.5 mm. wide, glabrous, the margins scabrous; spikelets obconic, 3.5–4 mm. long, the pedicel very short; second glume and sterile lemma equal, covering the fruit, prominently 3-nerved, appressed-hispid between the nerves, glabrous at the summit, the hairs golden or purple, those on the second glume exceeding the spikelet, those on the sterile lemma shorter than the spikelet, at maturity becoming purplish-black, clustered into stiff points standing away from the spikelet, appearing like a tiny crown; fruit 2–2.3 mm. long, oblong, striate, minutely hispid at the tip, pale green, turning chestnut brown at maturity.

Type in the U. S. National Herbarium no. 1,611,707, collected in open, sandy places between Barra do Corda and Grajahú, Maranhão, Brazil, March 4, 1934, by Jason R. Swallen (no. 3703).

Open sterile sandy land, northeastern Brazil.

MARANHÃO: Between Barra do Corda and Grajahú, *Swallen* 3703, 3704; between Carolina and Riachão, *Swallen* 4006, 4008, 4021.

GOYAZ: Philadelphia, *Swallen* 3921.

Centrochloa is closely related to the monotypic genus *Spheneria*.[2] These two genera apparently present a case of parallel development, the first from *Axonopus* since the spikelets are placed with the back of the fruit turned away from the rachis, and the second from *Paspalum* since the back of the fruit is turned toward the rachis. In both *Spheneria* and *Centrochloa*, the spikelets readily disarticulate from the pedicel, the articulation in the first being long and oblique and in the second small and round. Furthermore, the spikelets of *Spheneria* are not spurred as are those of *Centrochloa*, and the base of the fruit is long acuminate, while that of *Centrochloa* is blunt as in *Axonopus*.

[2] *Spheneria* Kuhlm. Comm. Linhas Telegraph. Estrat. Matto Grosso 67: 57. 1922. Based on a single species *S. setifolia* (Doell) Kuhlm.
Spheneria kegelii Pilger, Repert. Sp. Nov. Fedde 26: 228. 1929. Based on *Paspalum kegelii* C. Muell.
Paspalum kegelii C. Muell. Bot. Zeit. 19: 324. 1861. "Surinam, in arenosis prope Mariepaston Majo 1846: Kegel (Coll. no. 1316)."
Paspalum setifolium Doell in Mart. Fl. Bras. 2[2]: 61. 1877. "Habitat in regione Amazonica prope Manaos (Spruce n. 884 et 1360)."
Spheneria setifolia Kuhlm. Comm. Linhas Telegraph. Estrat. Matto Grosso 67: 57. 1922. Based on *Paspalum setifolium* Doell.

BOTANY.—*New species of the genus* Dimorphandra *Schott section* Pocillum *Tul.*[1]

ADOLPHE DUCKE, Jardim Botanico, Rio de Janeiro. (Communicated by E. P. KILLIP.)

The genus *Dimorphandra* may be divided into two sections: *Eudimorphandra* and *Pocillum*, which are so natural that it would perhaps be better to consider them as subgenera. They are chiefly distinguished by the fruits, and each has a different geographical distribution. The species of *Eudimorphandra* occur throughout the Amazonian hylaea inclusive of Guiana and in tropical Brazil as far south as Rio de Janeiro and the State of S. Paulo. *Pocillum*, however, is strictly limited to the hylaea.

This latter section now contains 15 species, 10 of which are found in the Brazilian states of Pará and Amazonas, and 5 in British Guiana. One of them, *D. macrostachya* of the slopes of Mount Roraima must be included in the flora of both countries, as well as in that of Amazonian Venezuela. Here occurs also the Brazilian *D. pennigera*. The sole species found in French Guiana, *D. polyandra*, is, according to Sandwith, probably an anomalous form of *D. hohenkerkii* of British Guiana. *D. pennigera*, collected in the Brazilian and Venezuelan Upper Rio Negro, must certainly exist in the neighbouring Colombian territories, and *D. gigantea* grows at the frontier of Peru.

[1] Received January 17, 1934.

The habitat of the majority of the species is the upland forest with moist sandy soil, having a surface layer of acid black humus. Here the red-flowered species may be counted among the most elegant and showy trees. Some species, however, are small trees of dry savannas (in Brazil, *campinas*) of white sand. None of them was found in the periodically overflooded Amazonian lowlands.

I have examined herbarium samples of 9 Brazilian and one British Guiana species (*D. congestiflora*, cotype, received from Kew Gardens.) For the four or five remaining species, I am content with the good descriptions in Sandwith's review[2] of the British Guiana *Dimorphandra*. The type specimens of the new species described below are preserved in the Jardim Botanico of Rio de Janeiro; cotypes or duplicates of all species I collected have been distributed to the United States National Museum and to the principal botanical institutions of Europe. Cotypes of *D. gigantea* have been sent to Yale University School of Forestry, accompanied by a wood sample.

KEY TO THE SPECIES OF DIMORPHANDRA SECTION POCILLUM

A—Laminae of the staminodes coherent in the bud, forming a hood-like piece, deciduous at the opening of the flower.

Staminodes anantherous. Flowers relatively large, distinctly pedicellate, white, later becoming yellowish or dirty reddish.

Pinnae 13–21-jugate, leaflets 21–48-jugate. Racemes very long. Amazonian estuary and environs; Rio Trombetas.

D. velutina Ducke.

Pinnae 6–10-jugate, leaflets 20–30-jugate. Racemes shorter. Rio Negro, Cassiquiare and environs of Roraima.

D. pennigera Tul.

Pinnae 1–2-jugate, leaflets 4–8-jugate. Racemes shorter than those of the first species. Manáos.

D. vernicosa Benth

Staminodes with a rudimentary anther. Flowers pedicellate. Pinnae 9–12-jugate; leaflets 20–40-jugate. Not seen. British Guiana.

D. cuprea Sprague & Sandw.

B—Staminodes free.

Staminodes anantherous. Flowers pedicellate, white; petals sericeous-pilose within. Pinnae 2-jugate; leaflets 3–5-jugate, large for this genus. Not seen. British Guiana.

D. davisii Sprague & Sandw.

[2] Kew Bull. Misc. Inf. 1932: 395. 1932.

Staminodes with a rudimentary anther. Petals glabrous within.

Pinnae 1–3-jugate; leaflets 4–7-jugate, fairly large. Flowers pedicellate red. Manáos.

D. ignea sp. nov.

Pinnae 3–5-jugate; leaflets 7–12-jugate, smaller. Flowers pedicellate, red. Plants not seen.

Fertile stamens 5. British Guiana.

D. hohenkerkii Sprague & Sandw.

Fertile stamens 8–10 (perhaps anomalous?). French Guiana.

D. polyandra R. Ben.

Pinnae 3–10-jugate; leaflets 10–33-jugate, small. Flowers sessile.

Leaflets nearly glabrous. Spikes very long and thin; flowers fire-red; calyx distinctly pubescent. Eastern part of the State of Pará.

D. glabrifolia sp. nov.

Lower surface of leaflets sericeous-pubescent. Spikes very long and thin; flowers orange-red; calyx distinctly pubescent. British Guiana.

D. congestiflora Sprague & Sandw

Lower surface of leaflets red brown, ciliolate. Spikes shorter but thicker; flowers of a palish orange color; calyx nearly glabrous. Northwestern part of the State of Pará.

D. campinarum Ducke.

Pinnae 11–17-jugate; leaflets 22–33-jugate, small. Flowers subsessile (pedicel about 0.5 mm. long), red. Manáos.

D. coccinea sp. nov.

Pinnae 13–22-jugate; leaflets 30–54-jugate, very small. Flowers orange-ferruginous, subsessile (pedicel about 0.5 mm.). Indumentum of young branchlets, petioles, peduncles, etc., relatively thin, tomentous. Rio Curicuriary tributary of the Upper Rio Negro.

D. ferruginea sp. nov.

Pinnae 18–17-jugate; leaflets 32–54-jugate, very small. Indumentum of young branchlets, petioles, peduncles, etc., velvet; leaflets nearly glabrous. Tabatinga.

D. gigantea sp. nov.

C—Incompletely known species, of the affinity of *pennigera* according to Bentham. Laminae of the staminodes deciduous, unknown. Pinnae 6–12-jugate; leaflets 17–25-jugate, small. Flowers pedicellate, red (according to Schomburgk). Not seen. Environs of Roraima.

D. macrostachya Benth.

Dimorphandra ignea Ducke, sp. nov.

Arbor 20–35-metralis ramulis foliisque novellis et inflorescentiis tenuiter canoferrugineo-tomentellis. Folia petiolo modice longo, crasso; pinnae 1–3-(saepius 2)-jugae; foliola 4–6-(rarius 7)-juga, brevissime (1–2 mm.) petiolulata, 40–90 mm. longa et 15–45 mm. lata, oblonga vel elliptico-oblonga, basi acuta, apice minime acuminata vel acuta vel obtusa et saepe retusiuscula, coriacea, supra nitida, subtus subopaca et pallidiora, tenuissime penninervia. Racemi 2–7, vulgo 200–300 mm. longi, anthesi plena ad 15 mm. crassi, sat breviter pedunculati, rhachidibus crassis. Flores ignei, numerosissimi, pedicellis 1–1.1/2 mm. longis; calix 1.1/2–2 mm. longus et latus, campanulatus, lobis brevissimis, extus canopuberulus; petala 3–4 mm. longa extus sparsim griseopuberula caeterum glabra; stamina 5, vulgo 4–5.1/2 mm. longa, glabra, petalis longiora; staminodia 5, circa 6 mm. longa, libera, glabra, clavato-spathulata, basi longe stipitata, apice anthera rudimentari coronata; ovarium subsessile dense fulvovillosum. Legumen ut in *D. vernicosa*, sutura superiore fortius bialato-dilatata.

Habitat circa Manáos (civ. Amazonas), sat frequens in silva non inundabili leviter paludosa solo silico-humoso secus rivuli Mindú cursum superiorem et prope cataractam altam fluminis Tarumá ubi 27–5–1932 florifera (leg. A. Ducke, H. J. B. R. no. 23,265).

This new species agrees in the leaves with *D. vernicosa*, but belongs, on account of its flowers, to a very different group of species.

Dimorphandra glabrifolia Ducke, sp. nov.

Dimorphandra macrostachya Ducke, Archiv. Jard. Bot. Rio de Janeiro 4: 39. 1925, non Benth. 1840.

Arbor magna usque 40 m. alta, rarius mediocris. Ramuli novelli, foliorum petioli et rhaches inflorescentiaeque tenuiter cano-vel ferrugineo-tomentosi. Folia vulgo breviter petiolata; pinnae 3–10-jugae; foliola 10–26-juga, sessilia, maiora usque ad 22 mm. longa et 6 mm. lata at saepius 16 mm. longitudine et 4 mm. latitudine non excedentia, apicalia et praesertim basalia gradatim minora, lineari-vel subobovato-lineari-oblonga, basi obliqua apice levissime retusiuscula, margine revoluto, coriacea, supra rugulosa glabra nitida, subtus pallidiora opaca subglabra (pilis minimis sparsis) costa prominente. Spicae 1–6, usque ad 380 mm. longae anthesi plena 10–14 mm. crassae, vulgo breviter pedunculatae, rhachidibus crassis. Flores inodori ignei numerosissimi, sessiles vel subsessiles pedicello 1/2 mm. longo; calix 1–1.1/2 mm. longus, 2–2.1/2 mm. latus, cupularis, breviter dentatus, tenuiter pubescens; petala 3–3.1/2 mm. longa, glabra; stamina 5, glabra, 3.1/2–4.1/2 mm. longa; staminodia 5, libera, 4.1/2–5 mm. longa, glabra, longe stipitata laminis clavato-spathulatis apice anthera rudimentari coronatis; ovarium subsessile dense et longe fulvidovillosum. Legumen forma ut in reliquis hujus sectionis speciebus, usque ad 200 mm. longum et ad 90 mm. latum, adultum glabrum, seminibus 14–18 mm. longis, 8–10 mm. latis crasse albuminosis.

Habitat sat frequens in silva non inundabili at plus minus paludosa solo silico-humoso secus rivulos "nigros," in civitatis Pará parte orientali: prope flumen Aramá in aestuario amazonico, H. J. B. R. no. 20,203 (speciei typus); prope Belem do Pará, Herb. Amaz. Mus. Pará no. 2,149 et 16,846; in insula Collares, H. A. M. P. no. 12,651; prope Sao Caetano de Odivellas ad ostium fluvii Pará, H. J. B. R. no. 11,817; sub radicibus montis Parauaquara inter Prainha et Almeirim, H. J. B. R. no. 10,956. Specimina omnia legit A.

Ducke, exceptis no. 2,149 et 11,817 a M. Guedes et P. Le Cointe lectis. Prope Santa Izabel viae ferreae inter Belem et Bragança, et circa Gurupá visa. In horto botanico Rio de Janeiro culta.

This species was erroneously identified as *D. macrostachya* Benth. by Huber and by myself, according to the original diagnosis where the inflorescences are described as spikes and not as racemes; we have distributed it under this name and I have mentioned it under the same name in various papers. Recently, Sandwith[3] in his most valuable revision of the *Mora* and *Dimorphandra* of British Guiana re-established the true identity of *D. macrostachya* and re-described the type. According to the same author, the Pará species is a very different plant, closely allied to *D. congestiflora* Sprague et Sandw.; this latter, however, has the under surface of the leaflets densely yellowish-sericeous. The leaflets of the numerous specimens of the Pará plant vary considerably in their dimensions, but are constantly glabrous or subglabrous; their lower surface is scarcely paler than the upper, and not sericeous.

Dimorphandra coccinea Ducke, sp. nov.

Arbor mediocris vel magna, ramulis junioribus, foliorum petiolis et rhachidibus inflorescentiisque canotomentellis. Folia petiolo sat longo et robusto; pinnae 12–16 (rarissime 11-vel 17)-jugae; foliola 22–33-juga, sessilia, 7–11 mm. longa et 2–4 mm. lata (basalia et apicalia gradatim breviora), lineari-oblonga, basi obliqua et auriculata, apice retusiuscula, coriacea, supra nitida saepe rugulosa, subtus pallidiora costa prominente et margine revoluto puberula, adulta caeterum subglabra. Spicae 2–7 rarissime 1, vulgo 280–380 mm. longae anthesi plena 12–16 mm. crassae, longiuscule pedunculatae rhachidibus crassis. Flores laete coccinei numerosissimi, subsessiles vel vix ad 1/2 mm. pedicellati; calix circa 1 1/2–2 mm. longus et parum magis latus, cupuliformis lobis brevissimis latis, minime puberulus; petala 3–4 mm. longa extus minime griseopuberula caeterum glabra; stamina 5, glabra, 4–5 mm. longa; staminodia 5, libera, glabra, ad 6 1/2 mm. longa laminis clavato-spathulatis longe stipitatis apice anthera rudimentari coronatis; ovarium subsessile dense et longe fulvidovillosum. Legumina vidi in arbore, forma ut in reliquis hujus sectionis speciebus.

Habitat circa urbem Manáos (civ. Amazonas) sat rara in silva non inundabili solo silico-humoso secus rivulos, locis Cachoeira Grande, Estrada do Tarumá et Colonia dos Francezes, loco ultimo florifera 20-8-1931, legit A. Ducke, H. J. B. R. no. 23,968.

Allied to *D. glabrifolia*, but with very elegant multipinnate and multijugate leaves. The flowering tree is of a remarkable beauty.

Dimorphandra ferruginea Ducke, sp. nov.

Arbor parva vel vix mediocris como ampla umbelliformi, ramulis novellis, foliorum petiolis et rhachibus inflorescentiisque tenuiter et brevissime canoferrugineo-tomentosis. Folia sat longe petiolata; pinnae 13–22-jugae; foliola 30–54-juga, sessilia, maiora usque ad 5 mm. longa et ad 1 mm. lata (basalia et praesertim apicalia minora), lineari-oblonga parum falcata, basi parum obliqua subauriculata, apice subtruncata minime retusiuscula margine revo-

[3] Kew Bull. Misc. Inf. 1932: 395–406. 1932.

luto, coriacea, supra nitida saepe rugulosa glabra, subtus opaca sat dense pilosa costa prominente dense ferrugineovillosa. Racemi 1–5, vulgo 300–400 mm. longi, anthesi plena 12–14 mm. crassi, longiuscule pedunculati rhachidibus crassis. Flores anthesi incipiente dilute aurantiaci demum ferruginei, numerosissimi, pedicellis anthesi circa 1/2 mm. demum 1 mm. longis; calix 1–1.1/2 mm. longus, 2–2.2/3 mm. latus cupuliformis breviter dentatus, extus ferrugineo-puberulus; petala 3–3.1/2 mm. longa, glabra; stamina 5 glabra, 4–5 mm. longa; staminodia 5 libera, ad 6 mm. longa, glabra, laminis clavato-spathulatis longe stipitatis, apice anthera rudimentari coronatis. Ovarium dense et longe fulvovillosum. Legumen ignotum.

Ad ripas saxosas et arenosas fluminis Curicuriary, Rio Negro superioris affluentis (civ. Amazonas), 26-12-1931 flor., leg. A. Ducke, H. J. B. R. no. 23,969.

Allied to *D. campinarum* in the structure and color of the flowers, but differing in the much more numerous pinnae and leaflets.

Dimorphandra gigantea Ducke, sp. nov.

Arbor 50-metralis et forsan altior, trunco basi radicibus tabularibus alte emersis. Ramuli novelli, petioli, pedunculi rhachidesque foliorum et inflorescentiarum pilis densis rufis subvilloso-velutini. Foliorum petiolus sat longus, validus; pinnae 18–27-jugae; foliola 32–50-juga, maiora 7 mm. longa vix ultra 1 mm. lata (basalia et apicalia semper minora), sessilia, linearioblonga leviter falcata, basi truncata parum obliqua subauriculata, apice obtusa vel acutiuscula, margine non revoluto, subcoriacea, supra glabra parum nitida, subtus pallida opaca subglabra costa minime pilosula. Racemi 7–14, in speciminibus nostris juveniles, usque ad 300 mm. longi, longe longe (usque 130 mm.) pedunculati, tenues rachidibus crassis. Flores solum in alabastris novissimis adsunt, subsessiles (anthesi forsan breviter pedicellati), numerosissimi, canopilosuli, petalis nondum e calice exsertis, staminibus fertilibus 5 glabris, staminodiis jam bene evolutis 5 liberis glabris lamina anthera rudimentari coronata, ovario fulvidovilloso. Leguminis valvas putredine plus minus destructas vidi sub arbore, iis speciei *D. velutina* similes.

Habitat in silva non inundabili prope Tabatinga (ad civitatis Amazonas fines occidentales), leg. A. Ducke 28-9-1931 cum ligno no. 22, H. J. B. R. no. 23,789.

One of the tallest trees of the forest near Tabatinga. At first glance it suggests, in its indument and leaves, *D. velutina*, a species with hood-like anantherous coherent staminode-laminae. The proposed species is fairly closely allied to *D. ferruginea*, but is at once distinguished from that species by its size and by the velvety indument of the young branchlets, which form a contrast with the nearly glabrous leaflets. The flowers I have collected, but their color is not apparent.

SCIENTIFIC NOTES AND NEWS

Prepared by Science Service

NOTES

Last Winter's Weather.—A survey of the winter of 1934–35 by the U. S. Weather Bureau shows that the season was warmer than usual over almost the entire United States. Between 85 and 90 per cent of the country had super-normal temperatures for the months of December, January and February. Lower-than-average temperatures ruled in a limited area in the Northeast, and along a narrow Atlantic coast strip the records show a just-about-average winter. This warm-winter trend has now lasted for nearly twenty years.

February in particular was warmer and drier than average. This was especially the case in the Northwest. For example, at Bismark, N.D., only one February in the past sixty years has been warmer than the month just closed. Eleven of the past twelve Februaries in that region have been warmer than normal, and the average temperature for all twelve has been ten degress above the normal for the month.

Weather observers in the mountain areas of the West, where summer irrigation must depend on snows of the preceding winter, reported encouraging conditions at the end of winter. In the mountains of the Pacific Coast states especially the snow packs were deep and heavy, and on the whole much greater than last year's; at the same time the water already in the soil was more abundant. Farther east, in the Great Basin and Rocky Mountain regions, soil water was not so nearly up to standard, due to cumulative drought of several years, but the snow supplies on the upper slopes were encouragingly large.

National Bureau of Standards.—New knowledge of propeller vibration and the possible causes of why propellers break in midair is reported by Dr. WALTER RAMBERG, PAUL S. BALLIF and MACK J. WEST. Such propeller failures, while rare compared with the number of propellers in service, usually have serious consequences. Often the flying broken parts rip through the wings of a plane, cause a wreck and sometimes loss of life.

Because it was almost hopeless to try to measure the size of propeller vibrations and the forces in blades while they were whirling rapidly, the government scientists produced a comparable effect by working backward.

Instead of the propeller receiving its vibrations during actual flight the experimental test was performed with a fixed propeller made to undergo the vibrations by having its propeller shaft twisted back and forth mechanically. Thus strains and stresses similar to those encountered during normal operation were set up and could be measured. It was found the vibrations were those of resonance wherein tiny forces, timed at just the right period, built up and amplified one another until the total effect was enough to snap the blade. For the experimental propellers two vibration periods were found; one at the frequency of 35 times a second and the other 130 times a second. For the lower frequency of vibration it was found that the greatest stresses occurred at the middle of the propeller blade.

Smithsonian Institution.—Iroquois murderers were compelled by tribal code to remain on the scene of the crime until discovered, J. N. B. HEWITT of the Bureau of American Ethnology has learned in his studies of the cus-

toms of the Iroquoian tribes. When found by the relatives of the deceased, the criminal might either be killed on the spot, or he might be haled before the tribal council and payment of blood-money be arranged by his relatives. The latter procedure was the one more usually adopted.

Children's Bureau, U. S. Department of Labor.—The large number of deaths of American mothers in childbirth as compared with mothers in other countries cannot be explained away by laying the blame on methods of reporting, it appears from a study conducted by Dr. ELIZABETH C. TANDY.

"The official figure of the United States, which in the last few years has exceeded that of every country except Scotland, remains high no matter what method of assignment is used," Dr. Tandy states.

Differences in methods of assigning causes of deaths are not enough to explain the high maternal mortality rate in the United States, as compared with foreign countries. Even if the method of the country assigning the smallest proportion of deaths to the puerperal state were in use in the United States, the United States figure would still exceed that of all 16 countries included in the study, except Australia, Canada, Chile and Scotland.

Lack of exact knowledge of the antirachitic effect of foods fortified with vitamin D, especially the so-called vitamin-D milk which is now being prepared by three different methods and widely distributed, has made it imperative to work out a method by which the relative merit for infant feeding of these various milks could be determined and comparisons made with standard substances such as cod-liver oil and viosterol containing vitamin D. The children's Bureau through its division of child and maternal health, is now carrying on, in preparation for future studies of vitamin-D milks, a series of clinical tests of the antirachitic value of cod-liver oil and viosterol. These substances are provided for the purpose by the Food and Drug Administration of the Department of Agriculture, which carries out the biological assays for vitamin D. Assistance and advice are being given by the Senior Chemist of the Bureau of Chemistry and Soils of the Department of Agriculture.

NEWS BRIEFS

The recently organized Washington Chapter of the Society for Experimental Biology and Medicine held its first scientific meeting at the Cosmos Club on February 25. The officers of the chapter are: president, Dr. VINCENT DU VIGNEAUD; secretary, Miss SARAH BRANHAM.

PERSONAL ITEMS

Dr. ISAIAH BOWMAN, director of the American Geographical Society, chairman of the National Research Council, and director of the Science Advisory Board, has been elected president of the Johns Hopkins University.

Prof. ROBERT F. GRIGGS of George Washington University lectured on *Dionaea* before the Royal Canadian Institute, Ottawa, on the evening of March 16.